Capital Adjustment Patterns in Manufacturing Plants

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Abstract

A common result from altering several fundamental assumptions of the neoclassical investment model with convex adjustment costs is that investment may occur in lumpy episodes. This paper takes a step back and asks "How lumpy is investment ?" We answer this question by documenting the distributions of investment and capital adjustment for a sample of over 33,000 manufacturing plants drawn from over 400 four-digit industries. We find that many plants do undergo large investment episodes, however, there is tremendous variation across plants in their capital accumulation patterns. This paper explores how the variation in capital accumulation patterns vary by observable plant and firm characteristics, and how large investment episodes at the plant level transmit into fluctuations in aggregate investment.

Keywords: Investment, Capital, Spikes

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I. Introduction

Accurately modeling new capital investment at the micro and macro levels has proven difficult. In standard neoclassical models of investment (such as Eisner and Strotz 1963) and Hayashi 1982), assumptions, such as convex adjustment costs and reversibility, dictate that firms (representative agents) continuously and smoothly adjust their capital stock over time. While theoretically tractable, these models generally fail to adequately explain investment fluctuations (Abel and Blanchard 1986). The disappointing empirical performance of these investment models has caused economists to re-examine the potentially unrealistic assumptions of convex adjustment costs and reversibility. For instance, Rothschild (1971), and more recently Bertola and Caballero (1990), argue that adjustment costs faced by plants and firms possess non-convexities for a variety of reasons[1]. Another potential source of nonconvexity arises when capital goods are irreversible, as reviewed in Dixit (1992) and Pindyck (1991). The solutions to models which assume non-convex adjustment costs differ markedly from the solutions derived from standard neoclassical models. Instead of firms smoothly adjusting their capital over time, models that explicitly incorporate nonconvexities possess solutions where firms occasionally adjust their capital in discrete bursts when the capital stock falls (rises) below (above) a threshold level[2].

While a growing number of studies suggest that capital adjustments may occur in lumpy episodes, the supporting empirical research is more limited[3]. Also, whether or not

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1 The sources of speculated nonconvexities in the cost of capital adjustment include increasing returns, the cost of the equipment, costs associated with disruption, and installation costs.

2 Other underlying assumptions in neoclassical models are that capital is homogeneous and capital depreciates geometrically. Feldstein and Rothschild (1974) discuss the unrealistic nature of homogenous capital and geometric decay, and how changing these assumptions can result in lumpy investment patterns.

3 The literature which examines labor adjustments is more mature. The importance of large proportional adjustments in employment at the establishment level has been documented by Hamermesh (1989, 1993), and by Davis and Haltiwanger (1992).

capital adjustment is "smooth" or "lumpy" depends, in part, upon the level of aggregation and frequency of the data, and whether new investment is going towards expansion, replacement, or factor substitution. The few empirical investment studies that explicitly or implicitly incorporate non-convexities tend to focus on replacement investment. Examples include Rust (1988) with bus engines, and, for larger units of analysis, Cooper and Haltiwanger (1993) with automobile assembly plant retoolings.

Unfortunately, the handful of studies that incorporate or test for non-convexities cover only a small portion of manufacturing investment. This paper takes a step back and simply asks to what extent is investment lumpy by documenting the distributions of investment and capital adjustment for a sample of over 33,000 manufacturing plants drawn from over 400 four-digit industries. This sample is composed of a balanced panel of 13,702 plants that have continuous data from 1973 to 1988. The plants in the balanced panel account for 58% of aggregate investment and 85% of sample investment. The remaining portion of our sample, the unbalanced panel, contains over 19,000 plants, and allows us to focus on the investment patterns of plants that are exiting and entering. It is not our intention to specifically test one investment model against another in this paper. Instead, the goal of this paper is to present a series of previously unknown stylized facts that will serve as benchmarks for investment models.

We first examine the patterns of capital accumulation within plants and focus on the degree to which capital adjustment and investment are lumpy. Although many plants do experience a lumpy investment episode, there is tremendous variance across plants in the degree of their lumpiness. We focus on the relationship between the lumpiness of investment and observable plant characteristics, such as size, industry, and age. We find:

(1) Many plants occasionally alter their capital stocks in lumpy fashions. Of the plants in the balanced panel, over half experience a capital adjustment of at least 37% in one year, and by over 50% in two consecutive years.

(2) While many manufacturing plants do experience episodes of intense investment activity, 80% of the plants in a given year change their net capital stock by less than 10%. These relatively small changes account for 45% of total sample investment.
(3) With respect to plant characteristics, smaller plants, younger plants and high output growth plants have lumpier investment patterns. Additionally, plants that undergo an organizational structure change or switch industries also show more discrete capital adjustments.

Although investment is conducted at a the establishment level, firm level variables enter into plant level investment decision, as suggested in the large literature on the role of financing constraints. Therefore, although investment may be relatively volatile at the establishment level, investment may be smoothed at the firm level. We find:

(4) Plant-level capital accumulation patterns are considerably more lumpy than line-of-business, firm-level, or industry-level capital accumulation patterns.

Whether or not investment is lumpy also influences models of aggregate investment. Traditionally, neoclassical models of investment rely on a representative agent framework where convex adjustment costs smooth investment over time. However, increasing attention has recently been placed on unraveling aggregate fluctuations by examining the distribution of micro changes (e.g., Blanchard and Diamond 1990, Caballero and Engle 1993, and Davis and Haltiwanger 1992.) Bertola and Caballero (1992), examine a collection of firms making investment decisions in an uncertain environment and investment is irreversible. In this model, firms do not continually invest but invest in lumps, so in this model, aggregate fluctuations in investment is partially attributable to changing proportions of the population undergoing large investment episodes. Is this the correct way in which to view changes in aggregate investment? We then examine how plant level changes in capital and investment transmit in aggregate fluctuations in investment, focusing particularly on the role of investment spikes. We find:

> (5) Large investment projects in a small number of plants greatly impact aggregate investment. For our sample, 25% of expenditures on new equipment and structures go into plants that are increasing their real capital stock by more than 30%. However, these plants make up only 6% of the sample. For the population as a whole, investment is highly skewed. In 1977 and 1987 the 500 largest investment projects accounted for 35.7 and 32.1 percent of total manufacturing investment.
> (6) Periods of large aggregate investment are due, in part, to changes in the frequency of plants undergoing large investment episodes, though not necessarily large percentage changes in capital adjustments.

The paper proceeds as follows. Section II describes the dataset used in this study, along with summary statistics describing the volatility of capital adjustment. In section III, we focus our attention on the within plant patterns of capital adjustment. This section also examines how plant/industry characteristics influence plant-level capital adjustment patterns. Section IV discusses the correlation between large capital adjustments and fluctuations in aggregate investment. Section V concludes and describes our future research.

II. Data

The empirical growth rate distribution for capital is constructed from panel data on manufacturing plants for the period 1972-88. The establishment-level data are drawn from the Longitudinal Research Database (LRD), which is maintained at the U.S. Census Bureau, and contains establishment-level production data from the Annual Survey of Manufacturers (ASM). In this section we describe the sample design, basic attributes of the sample, and variable construction.

Sample Design

The sample of plants utilized in this study is a special subset of plants from the LRD. Plants must meet two requirements to be included in the sample. First, all plants must have a minimum of four years of continuous data, permitting the construction of a minimum of three capital growth rates for each plant. Given that the main focus of this paper is to describe within-plant variation in capital adjustment, having multi-year contiguous data is imperative. Second, there must be no perforations or "holes" in a plant's data. This second requirement ensures that we can construct capital stocks for plants using the perpetual inventory method. Note that the sample selection criteria do not require a balanced panel, and our sample contains a large number of births and deaths.

The resulting sample is admittedly quite select as it is biased towards larger and more successful manufacturing establishments. Smaller plants and plants with short lifespans will be systematically excluded from our sample. Table 1 presents the number and the average size of plants in the sample disaggregated by length of time in the panel. The sample contains 33,125 plants. Roughly, a third of the plants in the sample have lifespans of 6 years or less, a quarter have lifespans of 7 to 16 years, and a little over 40% span the entire period. The third column of Table 1 indicates that as the length of time in the panel increases plant size, measured as employment, increases. In comparison to the population these plants are quite large[4]. The average plant in the manufacturing population employed 58.2 workers in 1977 as opposed to 452.1 in our sample.

[4] The large plant size is partially due to the selection criteria used in the study and partially due to the ASM selection process. The ASM over samples large establishments and our subset uses the ASM as its universe.

Even though our sample is comprised of 33,125 plants out of the universe of approximately 900,000+ plants, the sample accounts for a substantial proportion of investment, shipments and employment for the manufacturing sector. Table 2 provides data on the proportion of investment, employment and shipments covered by our sample broken out by year from 1973-88. The top number in each row represents percent coverage of the entire sample in a year. The second number represents coverage for the 13,702 plants that appear in every year. The first column lists the year and the second through fourth columns give the proportion of total investment, total employment, and total shipments covered by our sample. The fifth column reports the average plant size measured in employment.

The plants in our sample account for 67%-75% of the total manufacturing investment expenditures, 46%-59% of total employment, and 64%-70% of shipments[5]. A pattern in the data, particularly for employment, is that coverage is declining over time. This is due, in part, to the fact that new plants are not added to the panel in 1986-88, since they do not meet the 4-year existence requirement. Additionally, the ASM undersampled births in the early-to-mid eighties, and this lowers the number of new plants entering the sample in the years 1980-85. Examining the lower number in each row (the coverage for plants that appear every year), two points are worth noting. While the continuous plants make up only a little over 40% of the number of plants in our sample, they account for over 80% of the total sample investment and roughly 75% of employment and output. Second, the pattern of declining employment and shipments coverage is also present in this subset of plants.

[5] There is a positive correlation between plant size and capital intensity. Therefore the sample, which is biased towards large establishments, covers a greater percentage of investment than employment.

The relatively high coverage rate is indicative of the fact that the plants in the sample are relatively large. The final column of Table 2 shows the average plant size for each year. In general, the average plant size stays roughly between 400-500 employees per year and tracks the overall business cycle. In years of expansion average employment is generally increasing while in recession years it is decreasing.

Capital Measurement

In order to measure plant-level capital growth rates, a capital series must be developed for each plant. In this paper we use the perpetual inventory method. The capital stock in period t for plant i, $K_{i,t}$, is defined as

$$K_{i,t} = K_{i,t-1}(1-\delta) + I_{i,t} \tag{1}$$

where δ represents the depreciation rate and $I_{i,t}$ is current period investment. The rate of depreciation, δ, is estimated for each three-digit industry by imbedding the depreciation parameter within a production function. The parameters of the production function are estimated simultaneously with the parameters of the investment stream (see Doms 1994 for details).

Utilizing the above measure for the capital stock we construct a net capital growth rates analagously to the employment growth rates of Davis and Haltiwanger (1992). The growth rate of capital for plant i at time t is computed as

(2) $$GK_{i,t} = \frac{I_t - \delta K_{i,t-1}}{.5 \cdot (K_{i,t-1} + K_{i,t})}$$

where $GK_{i,t}$ lies in the interval $[-2\delta,2]$. Note, this definition is accurate for continuing plants and newly opened plants. It is not appropriate for closing plants since it does not include a retirement's term. For the analysis which follows we do not include either the growth rate of plants in the year they are opened or in the year they are closed[6].

Figure 1 presents two distributions, the density of $GK_{i,t}$ and the density of $GK_{i,t}$ weighted by $I_{i,t}$. The figure shows that 55.1% of plants in a year increase their capital stock by less than 2.5%, while 10% of plant year observations increase their capital stock by more than 20%. However, the few plants that do undergo large changes contribute significantly to the level of aggregate investment. The weighted distribution shows that 25% of investment is going to plants increasing their capital stock by more than 30%. At the other end of the distribution, 19.2% of investment is occurring in plants changing their capital stock by less than 2.5%.

III. Plant-Level Capital Accumulation Patterns

In this section we examine the patterns of plant-level investment and capital growth, focusing especially on those periods when plants undergo large changes to their capital stocks. The section presents some basic statistics on capital growth rate and investment

[6] Unfortunately, the above expression ignores early retirements in the construction of the capital stock. The LRD does contain some data on retirements but these data appear to contain significant errors. The constructed growth rate is therefore a relative measure of new capital accumulation net of depreciation.

spikes, and examines how these episodes vary across industry and vary by plant characteristics such as plant size and age.

Basic Statistics from the Balanced Panel

For each plant with 17 years of data, we rank their capital growth rates from highest to lowest, so that their maximum growth rate is rank 1, and their lowest growth rate is rank 16. Throughout this paper, the rank 1 growth rate is denoted by MAXGK. Figure 2a presents the means and medians of these ranked growth rates, so the first set of bars in figure 2a shows the mean and median MAXGK. The next set of bars shows the means and medians of the secondary largest growth rates, and so on. These bars indicate that the mean MAXGK slightly exceeds 46%, while the median is 36%. The means and medians drop off significantly after rank 1. Figure 2a illustrates that plants with 17 years of data experience, on average, a few periods of intense capital growth, and many periods of relatively small capital adjustment: of the 16 capital growth rate ranks, 12 possess means and medians between -10% and +10%.

Besides the growth rate of the capital stock, we are also concerned with episodes of investment that account for a large share of the plant's investments over time. Figure 2b plots the mean proportion of total 16 year investment that occurs in each year. For instance, the left most bar represents that the average plant experiences a one-year investment episode that accounts for 24.5% of its total real investment spending over the 16 year interval. The secondary growth rate accounts for 14.7%, and the third highest accounts for 10.9% of investment. This implies that, on average, half of a plant's total investment over the 1973-88 period, is performed in three annual investment episodes. An important point is that while a significant portion of investment occurs in lumpy episodes, plants still invest in every period.

To give a flavor of the variability that occurs across industries, Appendix A presents Figures 2a and 2b for 18 different four-digit sectors[7]. With respect to the growth rate distribution (Figures A.1), Womens and Misses Dresses (2335), Computers (3573), and Semiconductors (3674) have mean MAXGK's in excess of 70 percent. Low growth industries are Steel Blast Furnaces (3312), Petroleum Refining (2911), and Printing (2751). In terms of the investment distribution, Womens and Misses Dresses (2335), Industrial Gases (2813), and Hydraulic Cement (3241) have particularly large investment spikes. In fact Industrial Gases has the largest investment spike in the balanced panel. If one examines the maximum investment spike for the set of 324 industries where there are ten or more plants in the balanced panel (Figures A.2), ten percent have maximum investment spikes under .20, 80 percent have maximum investment spikes between .20 and .30, and the remaining 10 percent have maximum investment spikes exceeding .30.

In addition to cross-industry differences, we also present capital accumulation patterns disaggregated by plant size.[8] Figures A.3 and A.4 present the capital growth rate ranks and mean investment share ranks disaggregated into plant size quintiles. The basic result is that smaller plants have higher maximum growth rate and larger maximum investment shares than the largest plants. That is, as plant size increases, investment expenditures become smoother. We explore the relationship between size and the lumpiness of investment in more detail below.

Statistics for Other Data Samples

[7]In this analysis, we only consider industries with ten or more plants. This was done to meet data confidentiality requirements.

[8] In previous empirical work by Dunne, Roberts and Samuelson (1989) and Evans (1987) which examines firm growth, plant size is found to be an important determinate of plant growth.

The plants that span our sample period account for 85% of total sample investment, however, they make up only 40.1% of the 33,125 sample. We replicate Figures 2a and 2b using plants that have seven years of data[9]. These results are shown in Figures 3a and 3b. The mean MAXGK for this group of plants is 32%, which is much less than the comparable figure for the 17 year sample. Part of the reason for the lower figure is that the 7 year group contains births and deaths: the mean MAXGK for births is 34%, while deaths have a mean of 26%. The maximum investment episode (Figure 3b) accounts for 46% of investment over the seven years of existence.[10]

In constructing figures 2a and 3a, we have imposed a calendar year interval when measuring the capital growth rates and investment shares. However, as a result of our data being collected on an annual level, some projects that are completed within a 12 month period will be divided across consecutive calendar years. Therefore, MAXGK is a lower bound on the maximum capital adjustment that occurs within a 12 month period. We construct an upper bound on the maximum capital 12 month capital adjustment by obtaining the maximum consecutive two year growth rate, MAX2GK. Table 3 reports the frequency distribution of the MAXGK and MAX2GK by length in panel. The three panel length groups are 4-7 years, 8-16 years, and 17 years. The last columns give the distributions for the total sample. Table 3 indicates that short-lived plants have relatively low MAXGK's and MAX2GK's.[11] For instance, 56.5% of plants with 4-7 years of data have MAXGK's less

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[9] We chose this group of plants only to illustrate that some of the general trends in figures 2a and 2b are not solely due to sample selection.

[10] As the length of time in panel decreases, the share of total investment occurring in any period will have a tendency to increase. For plants with 16 investment periods, a uniform distribution of investment would have 6.25% of investment in each year, while a 6 year distribution would have 16.6%.

[11] Recall that the capital growth rate in the start-up year or in the year of closing is not included in the calculations.

than .20, whereas for the plants in the panel for 8-16 years and 17 years, the proportion of plants with MAXGK's less than .20 is 32.1% and 22.8%, respectively.

It is clear that in our sample of plants the distribution of investment is skewed with a small number of plants accounting for a relatively large share. This is also true in the population as a whole. Table 4 gives the share of total investment for 1977 and 1987 accounted for by the top 100 investing plants, top 500 investing plants, top 1,000 investing plants, etc. Also given on Table 4 are the analogous figures for output, employment, and capital stock ranked by greatest output producing, highest employment and largest capital stock plants, respectively. The overall message is relatively clear. A small number of plants account for a large fraction of investment, output, employment, and capital stock. 32.1 percent of investment occurs in the top 500 investing plants in 1987 and 35.7 percent in 1977. Note that 500 plants make up only 0.14 percent of the entire population. A similar pattern is found in the output, employment, and capital stock columns, however, employment and, to a lesser extent, output is not nearly as concentrated as investment.

Firm and Line-of-Business Investment

Up to this point the unit of observation has been the plant, however, there are many arguments which suggest that the investment decisions of a plant are made at the divisional or firm level. In this section, we construct the investment distribution at the two-digit industry line-of-business level, the firm level, and the four-digit industry level. The sample used to construct the plant, line of business and firm, statistics is a subset of the balanced panel. First, only those plants that remain with a single firm for at least 14 out of the 16 years are used. Second, only those plants that belong to firms with at least three plants are kept. Given these requirements, only 5,822 plants out of 13,702 plants in the balanced panel remain, representing 648 firms and 955 lines of business. Note, however, that these plants make up 72.5% of the balanced panel investment.

The basic story in Figure 4 is that the higher the level of aggregation, the smoother is the investment distribution. Examining the height of largest investment spike episode, the mean plant maximum investment share is 24%. This is quite close to that reported in Figure 2b for the entire balanced sample. The mean maximum plant investment share drops to 17.1% at the line-of-business level and to 15.8% at the firm level. Using data on aggregate four-digit level investment, the primary investment share averages about 11.5% of total investment over the entire seventeen year period. The bottom-line is that firm-level investment patterns appear to be considerably smoother than plant-level investment patterns.

Industry and Plant Characteristics

The analysis, so far, shows considerable across plant variation in capital growth rates, suggesting some plants experience relatively smooth changes in their capital stocks while other plants undergo sizable jumps in their capital stocks. This section examines how capital accumulation patterns vary with observable plant characteristics.

Models of plant growth predict there should be systematic differences in plant growth within an industry (see Jovanovic 1982, and Pakes and Ericson 1989). Empirically, this plant-level heterogeneity has been documented in studies by Davis and Haltiwanger (1992), Dunne, Roberts and Samuelson (1989), and Pakes and Ericson (1989). A basic result of this research is that plant growth varies by identifiable plant-level characteristics, in particular, plant size and age.

To examine the relationship between plant characteristics and the capital accumulation process, we run a series of descriptive regressions with measures of capital lumpiness as the dependent variable and plant characteristics as independent variables. The main goal is to provide more detail on which kinds of plants experience lumpy capital accumulation episodes. Our plant-level measures of capital lumpiness are the standard deviation of capital growth (STDGK), the maximum single year capital growth rate (MAXGK), and the two-year growth rate (MAX2GK.) Table 5 reports the regression results for the unbalanced sample of plants. The regressions include controls for both plant and firm size. Plant size is modeled using a set of dummy variables representing plant-size quintiles. The quintiles go from smallest to largest with the quintile representing the largest plants omitted. The firm size variables are similarly defined. Two variables are included to capture potential changes in organizational structure and production mix that may affect capital accumulation patterns. The first variable is a dummy variable indicating whether a plant has changed ownership over it's panel lifetime. The second variable is a dummy variable which indicates whether the plant changes the two-digit industry in which the plant operates in over its panel lifetime. We control for the length of time in the panel and plant age with a set of cohort dummies and two age dummies. The cohort variables control for both time of entry and time of exit. Remember, that table 3 indicated that MAXGK and MAX2GK generally increased as panel length increased. Two age variables are included to capture differences in the age of plants that enter the panel in 1972. Finally, the regressions are all run with four-digit industry dummy variables. To conserve on space, the industry coefficients are not reported in the tables.

Generally, the three models produce qualitatively similar stories for the three measures of capital lumpiness. For the unbalanced panel (see Table 5), the degree of capital growth variance is a decreasing function of plant size, i.e. large plants being less variable. This is consistent with models of firm dynamics where the variance in growth, as measured by output or employment, is a decreasing function of plant size. With respect to firm size, the variation in capital generally decreases as size increases; however, the pattern is not nearly as monotonic nor large as in the case of plant size. The two variables which capture change in ownership and change in industry indicate that plants which undergo ownership changes or switch industries experience higher volatility in their capital growth rate and have larger than average capital growth rate spikes. This is consistent with the view that organizational and industry changes lead to changes in plant-level operations which affect capital accumulation decisions.

The entry and exit cohort variables indicate that for plants entering in the same period longer-lived plants have larger spikes and higher variance than short-lived plants. Thus, plants which ultimately close down have smaller capital growth spikes and lower variance. Note, however, the final retirement of the capital stock is not included in the underlying data. The two age variables indicate that plants which existed in 1963 and 1967 had on average lower variance and smaller capital growth spikes than plants starting in 1972 or later. This is also consistent with previous studies of plant growth and age.

Table 6 reports the regression results for the balanced panel. The main differences between Table 5 and Table 6 are that Table 6 drops the cohort variables (which are not relevant for the balanced panel) and we include a set of variables to measure plant output growth over the 16 year period. The growth variables are included to examine whether or not high output growth plants have a tendency to also have high capital growth variance. The plant growth rates are constructed using the growth in real output from 1972 to 1988. They are included as a set of five dummy variable with the highest output growth group omitted. With respect to plant size, firm size, industry switching, organizational change, and plant age, the results are qualitatively similar to those reported in Table 5. The growth rate variables indicate that low output growth plants have lower capital growth variances and lower capital growth spikes.

The regressions coefficients provide basic evidence of how capital growth varies with observable plant characteristics. However, on the whole, the plant and industry characteristics explain relatively little of variation in the standard deviation of capital growth or in the size of capital growth rate spikes. For the unbalanced panel, the amount of variation explained by plant and industry controls is between 15-20%. For the balanced panel, a substantially more homogeneous group of plants, the plant and industry variables account for 20-40% of the variation. In general this lines up with the results reported by Davis and Haltiwanger (1992) who report R^2's of similar magnitudes from analagous employment growth regressions.

IV. Aggregate Investment Fluctuations

This paper has so far focused on the predominance of large capital adjustments in plants and the variation across plants in their capital adjustment patterns. Increasing attention has recently been placed on unraveling aggregate fluctuations by examining the distribution of micro changes (e.g., Blanchard and Diamond 1990, Caballero and Engle 1993, and Davis and Haltiwanger 1992). In this section, we present some basic summary statistics on the relationship between aggregate fluctuations in investment, the uniformity of changes in capital, and the frequency of large capital adjustments.

Using the balanced panel, which annually accounts for approximately 58% of aggregate investment, we compute the frequency of plants that have their MAXGK and MAXI in a given year. Figure 5 presents these frequencies in addition to aggregate real investment over 1973-88. There are several items to note. The first is that the correlation between MAXI and aggregate investment is .59, which is significant at the 99% level. The correlation between MAXGK and aggregate investment, however, is not statistically significant. The is due primarily to the high frequency of MAXGK's in 1973 and 1974 which is not reflected in the aggregate data. Currently, we are searching for plausible explanations of this phenomenon.

Figure 5 conveys that aggregate fluctuations are correlated with the frequency of plants undergoing large investment episodes. An alternative way to summarize the relationship between aggregate investment and lumpy episodes is see if investment is more skewed or concentrated in high investment periods? To address this issue, we compute the herfindahl index for investment in each year and plot this series along with the aggregate investment series for the period 1973-88 in Figure 6. In general, the series move together. The correlation between the two series is .450 and is significant at the 90% level. An interesting feature to note in figure 6 is that in 1980 and 1988 there are periods of relatively high aggregate investment in which there are relatively low herfindahls. However, the two highest herfindahls are in the two years with the highest aggregate investment.

V. Conclusion

The objective of this paper is to present a series of stylized facts concerning the capital accumulation patterns for a large set of manufacturing plants. Although this paper is just a first step in examining plant-level investment behavior, the facts presented here are quite striking and raise a host of issues to be addressed in future research. In this paper we have shown that many manufacturing plants do indeed alter their capital stocks in lumpy fashions, and these large adjustments do account for a significant portion of a plant's total capital expenditures and aggregate investment. However, we also find tremendous heterogeneity in the capital accumulation patterns across plants, finding that the degree of lumpiness of capital adjustment varies considerably across plants. These facts certainly raise the question of whether traditional representative agent models based on convex costs of adjustment are adequate enough to examine the dynamics of investment and capital accumulation.

As a preview to our research underway, figure 7 presents the mean growth rates of capital, labor, and output over a five year period surrounding MAXGK. There are several items to note, including plant performance during the year of maximum capital adjustment and post spike performance. Arguments commonly posited for convex adjustment costs state that current period output is increasingly disrupted when capital is adjusted. Figure 7 shows that in the period of maximum capital adjustment in plants, that on average, labor increases by 4.8% and output increases by 5.9%. These results qualitatively hold when dissaggregated by industry. To more formally test the relationship between capital adjustment and output and labor growth rates, we are estimating the internal adjustment costs by measuring the degree to which current period output is disrupted by current period investment, and testing whether disruption is indeed convex with respect to new investment.

Another issue figure 7 raises is the role that new investment plays in production. New investment can go towards capacity expansion, machine replacement, and/or factor substitution. The stark result in figure 7 is that on average, plants do not experience large productivity or output increases up to two years after periods of significant capital adjustment. However, the variances that surround the mean values presented in figure 7 are substantial, indicating again that there is a tremendous amount of heterogeneity in the investment aims of plants.

Table 1. Sample Characteristics by Length in Panel.

Number of Years in Sample	Number of Plants	Percent of Plants	Average Number of Workers
4	5001	15.1	90.8
5	3341	10.1	115.2
6	1638	4.9	132.9
7	1614	4.9	182.8
8	1020	3.1	214.4
9	702	2.1	273.6
10	1082	3.3	266.2
11	976	2.9	310.1
12	486	1.5	289.5
13	695	2.1	362.6
14	894	2.7	393.1
15	1260	3.8	377.7
16	714	2.2	325.0
17	13702	41.4	568.3

Table 2. Sample Coverage by Year.

Year	Number of Plants	Investment Coverage (%)	Labor Coverage (%)	Production Coverage (%)	Average Employment
1973	24197 13702	71.9 58.6	58.6 43.5	69.2 53.0	456.8 598.7
1974	25076 13702	74.0 60.1	59.2 44.0	70.2 53.8	441.9 600.4
1975	26331 13702	73.2 58.8	58.8 44.0	68.7 52.7	383.2 551.8
1976	24647 13702	71.2 56.9	58.3 44.2	69.7 54.0	418.2 570.3
1977	23150 13702	70.9 57.1	56.5 43.5	67.9 53.1	452.1 588.2
1978	22216 13702	69.8 55.4	55.9 43.3	67.7 53.2	483.8 608.1
1979	21520 13702	73.3 59.3	55.3 43.2	68.4 53.7	507.9 622.2
1980	21597 13702	75.1 60.5	54.5 42.7	67.6 52.7	486.7 601.9
1981	21042 13702	75.3 60.5	54.2 43.2	67.1 52.6	486.9 595.8
1982	20526 13702	70.1 57.7	52.2 42.2	64.4 50.3	453.6 548.7
1983	20149 13702	75.8 61.1	52.1 41.9	66.0 51.1	451.4 534.7
1984	20135 13702	70.0 57.3	53.0 42.8	67.4 51.8	470.6 558.7
1985	20571 13702	72.7 60.8	52.7 42.9	65.7 50.6	448.3 547.6
1986	20978 13702	70.0 58.2	51.9 42.5	66.1 50.1	423.0 530.5
1987	19963 13702	67.2 56.7	48.1 40.2	64.6 48.3	427.2 520.7
1988	19287 13702	68.8 58.1	46.8 39.3	64.2 47.4	434.4 514.3

Table 3. MAXGK and MAX2GK Frequency Distributions by Length in Panel

	Length In Panel							
	4-7		8-16		17		Total	
Growth Rate	MAX	MAX2	MAX	MAX2	MAX	MAX2	MAX	MAX2
<0	4.44	4.44	.24	.24	0.00	0.00	1.67	1.67
0 to .1	37.53	33.45	14.71	11.04	5.46	2.79	19.15	15.75
.1 to .2	14.48	13.13	17.20	12.20	17.42	8.71	16.29	11.06
.2 to .3	9.29	8.88	13.36	12.35	17.75	13.47	13.85	11.55
.3 to .4	6.56	6.77	10.70	10.01	14.44	13.09	10.77	10.13
.4 to .5	4.76	4.93	8.35	8.66	11.33	11.61	8.30	8.54
.5 to .6	3.79	4.50	6.79	7.08	8.79	10.64	6.54	7.64
.6 to .7	4.56	3.80	5.36	6.10	6.18	8.53	5.42	6.29
.7 to .8	2.91	2.98	3.78	5.17	4.67	6.79	3.84	5.05
.8 to .9	1.87	2.32	3.15	3.82	3.41	5.50	2.79	3.98
.9 to .1	1.65	2.46	2.43	3.72	2.47	4.05	2.16	3.40
> 1.0	8.17	12.35	13.35	19.62	8.07	14.83	9.22	14.93
Mean of GK	.31	.40	.49	.62	.46	.61	.41	.53
Standard Deviation of GK	.44	.51	.48	.56	.36	.43	.42	.50

Table 4. Share of Investment, Employment, Shipments, and Capital Accounted for by the Top Plants in each Category.

	1987 Census of Manufactures: 358,567 Plants			
	Investment	Employment	Output	Capital Stock
Top 100 plants	.16204	.06344	.10077	.11888
Top 500 plants	.32154	.14057	.23031	.28882
Top 1000 plants	.41268	.18982	.30819	.38497
Top 5000 plants	.64769	.36233	.52581	.60963
Top 10000 plants	.74987	.47020	.62994	.70622
Top 25000 plants	.86863	.64043	.77045	.83002
Top 50000 plants	.93531	.77445	.86831	.90761
	1977 Census of Manufactures: 350,648 plants			
	Investment	Employment	Output	Capital Stock
Top 100 plants	.18172	.05932	.09005	.12883
Top 500 plants	.35657	.14584	.21638	.29359
Top 1000 plants	.44948	.20269	.29398	.39090
Top 5000 plants	.67240	.38958	.51551	.62407
Top 10000 plants	.76821	.50301	.62389	.72395
Top 25000 plants	.87931	.67753	.77172	.84548
Top 50000 plants	.94131	.80945	.87187	.91819

Table 5: Capital Accumulation Regressions: Full Sample
(standard errors in parentheses)

	STDGK	MAXGK	MAX2GK
Dependent Variable Mean	.139	.413	.529
Plant Size Quintile			
Smallest	.0859	.295	.354
	(.00271)	(.00941)	(.0111)
.	.0478	.186	.225
	(.00242)	(.00840)	(.00994)
.	.0307	.129	.153
	(.00226)	(.00786)	(.00930)
.	.0173	.0750	.0876
	(.00215)	(.00746)	(.00883)
Largest	Omitted	Omitted	Omitted
Firm Size Quintile			
Smallest	.0153	.0389	.0461
	(.00233)	(.00810)	(.00958)
.	.0121	.0390	.0485
	(.00211)	(.00732)	(.00867)
.	.00374	.0103	.00884
	(.00207)	(.00721)	(.00853)
.	.00619	.01546	.0158
	(.00206)	(.00716)	(.00848)
Largest	Omitted	Omitted	Omitted
Changed 2-Digit Industry	.0113	.05492	.0626
	(.00260)	(.00903)	(.0107)
Changed Ownership	.0104	.0473	.0561
	(.00146)	(.00506)	(.00599)

Table 5 Continued: Capital Accumulation Regressions: Full Sample
(standard errors in parentheses)

Cohorts First Year	Last Year	STDGK	MAXGK	MAX2GK
1972	1988	.0618	.378	.508
		(.00744)	(.0259)	(.0306)
	1985-87	.0548	.310	.408
		(.00774)	(.0269)	(.0318)
	1980-84	.0409	.183	.243
		(.00759)	(.0264)	(.0313)
	1975-79	.0209	.0534	.0740
		(.00749)	(.0260)	(.0308)
1973-76	1988	.0608	.431	.541
		(.00789)	(.0274)	(.0325)
	1985-87	.0560	.302	.379
		(.0103)	(.0360)	(.0426)
	1980-84	.0497	.142	.169
		(.00802)	(.0279)	(.0330)
	1975-79	.0336	.0414	.0544
		(.00889)	(.0309)	(.0366)
1977-81	1988	.0535	.3556	.4531
		(.00779)	(.0271)	(.0321)
	1985-87	.0497	.225	.280
		(.00891)	(.0310)	(.0367)
	1980-84	.0532	.209	.290
		(.00852)	(.0296)	(.0351)
1981-85	1988	.000807	.0489	.0762
		(.00748)	(.0260)	(.0308)
	1985-87	Omitted	Omitted	Omitted
If in 1963 Census		-.0269	-.0972	-.119
		(.00200)	(.00697)	(.00825)
Else if in 1967 Census		-.01487	-.0563	-.0682
		(.00270)	(.00938)	(.0111)
R^2		.192	.155	.172

Sample Size=32,359
All regressions include 4-digit industry controls.

Table 6: Capital Accumulation Regressions: Balanced Panel
(standard errors in parentheses)

	STDGK	MAXGK	MAX2GK
Dependent Variable Mean	.135	.461	.607
Plant Size Quintile			
Smallest	.0733	.00895	.00789
	(.00266)	(.00989)	(.0120)
.	.0406	.0329	.0346
	(.00243)	(.00931)	(.0113)
.	.0253	.0101	.0116
	(.00232)	(.00926)	(.0112)
.	.0137	.0116	.0169
	(.00219)	(.00914)	(.0111)
Largest	Omitted	Omitted	Omitted
Firm Size Quintile			
Smallest	.00255	.299	.354
	(.00227)	(.0116)	(.0140)
.	.00841	.164	.189
	(.00213)	(.0106)	(.0128)
.	.00186	.100	.117
	(.00212)	(.0101)	(.0122)
.	.00466	.0554	.0630
	(.00209)	(.00954)	(.0115)
Largest	Omitted	Omitted	Omitted
Growth Rate Quintile			
Smallest	-.0428	-.202	-.295
	(.00269)	(.0117)	(.0142)
.	-.0381	-.180	-.261
	(.00233)	(.0102)	(.0123)
.	-.0323	-.152	-.218
	(.00220)	(.00962)	(.0116)
.	-.0207	-.102	-.143
	(.00223)	(.00973)	(.0118)
Largest	Omitted	Omitted	Omitted
If in 1963 Census	-.0120	-.0566	-.0666
	(.00199)	(.00869)	(.0105)
Else if in 1967 Census	-.00645	-.0369	-.0430
	(.00258)	(.0113)	(.0136)
Changed 2-Digit Industry	.00422	.0292	.0311
	(.00248)	(.0108)	(.0131)
Changed Ownership	.00836	.0478	.0575
	(.00137)	(.00598)	(.00724)
R^2	.393	.234	.240

Sample Size=13,702. All regressions include 4-digit industry controls and controls for the year in which MAXGK occurs.

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Figure 1: Capital Growth Distributions
Unweighted and Weighted

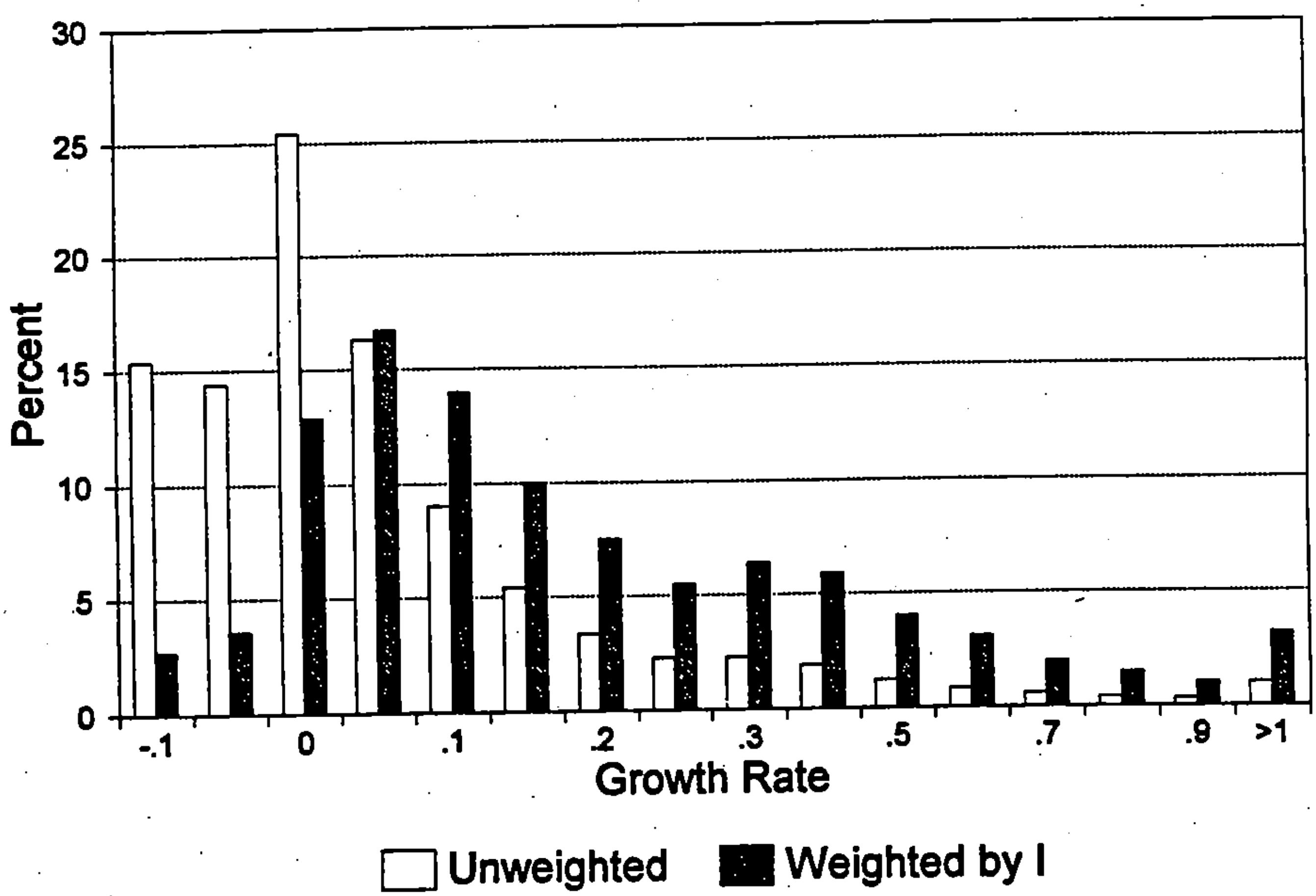


Figure 2a: Means and Medians of GK by Rank: 17 Year Sample

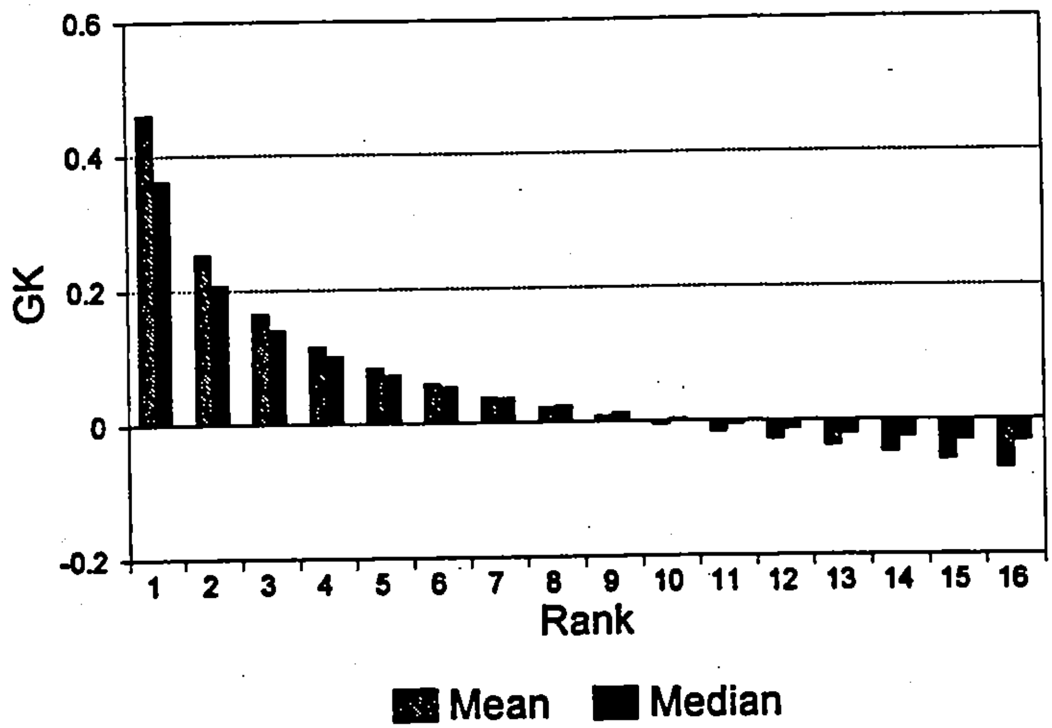


Figure 2b: Mean Investment Shares by GK Rank: 17 Year Sample

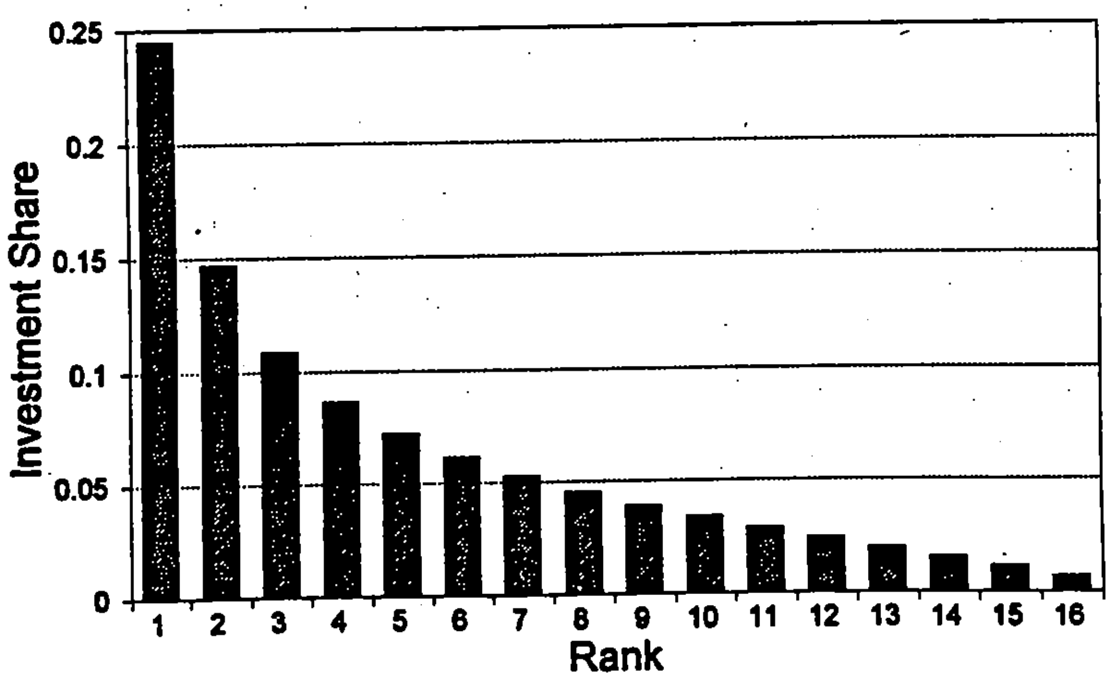


Figure 3a: Means and Medians of GK by Rank: 7 Year Sample

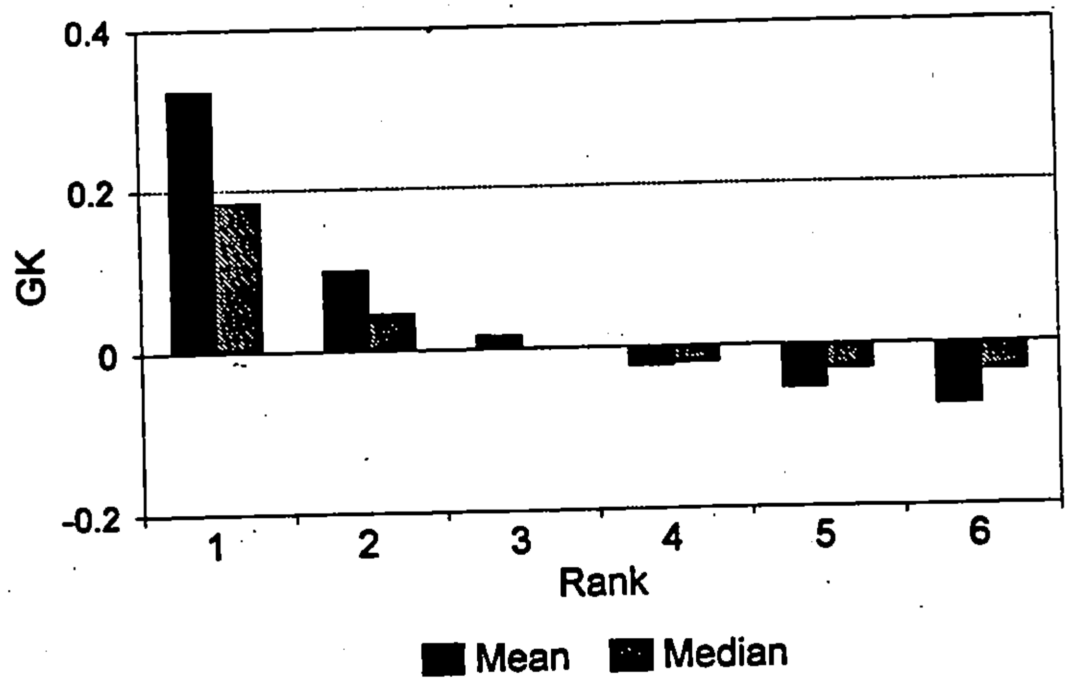


Figure 3b: Mean Investment Shares by GK Rank: 7 Year Sample

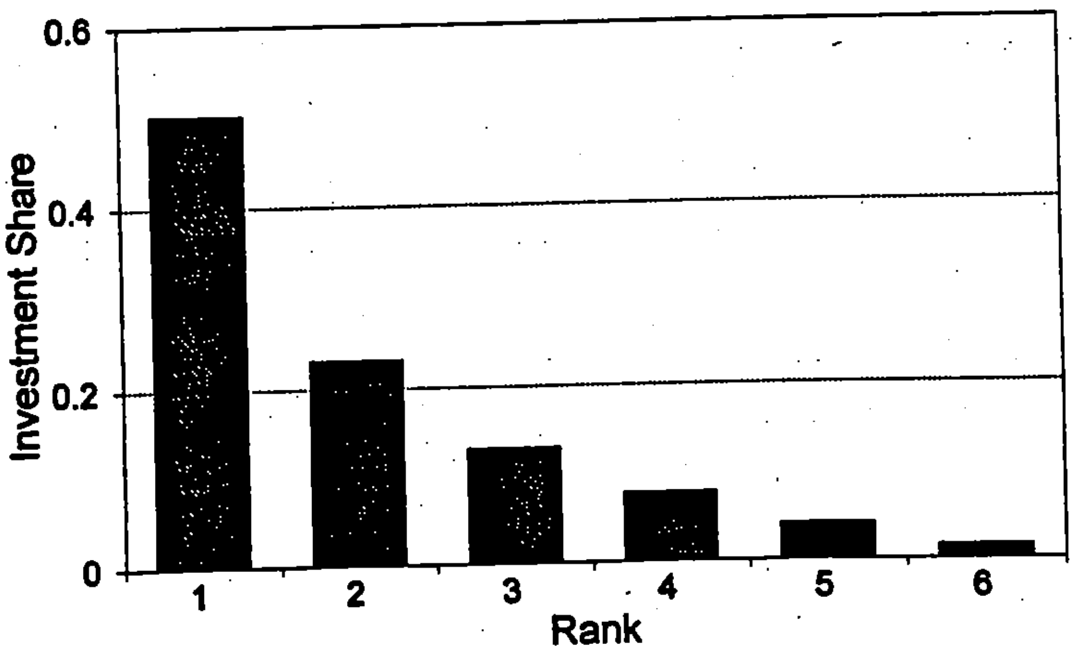


Figure 4: Mean Investment Shares at Different Levels of Aggregation

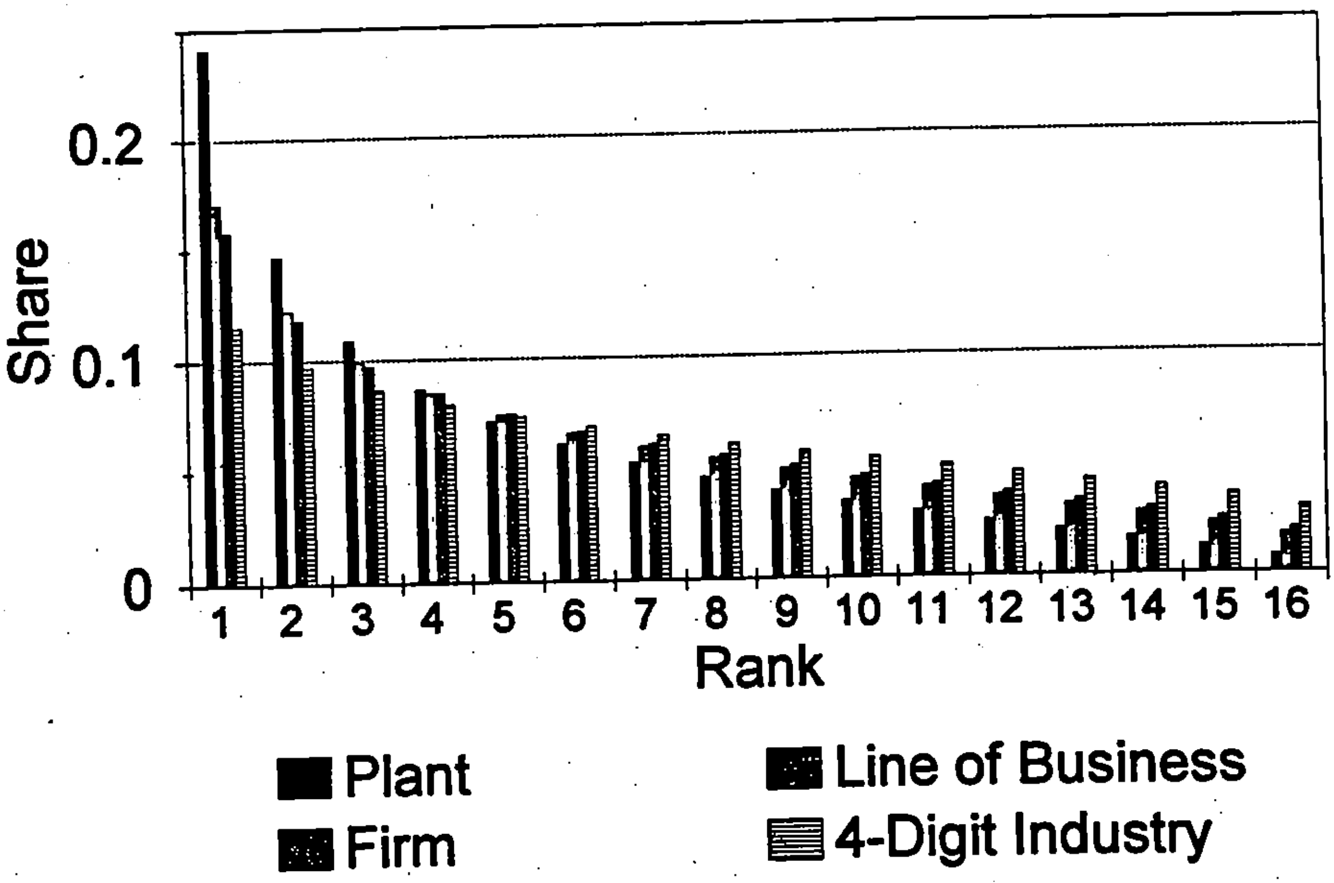


Figure 5: Aggregate Investment and Frequency of Plant Spikes

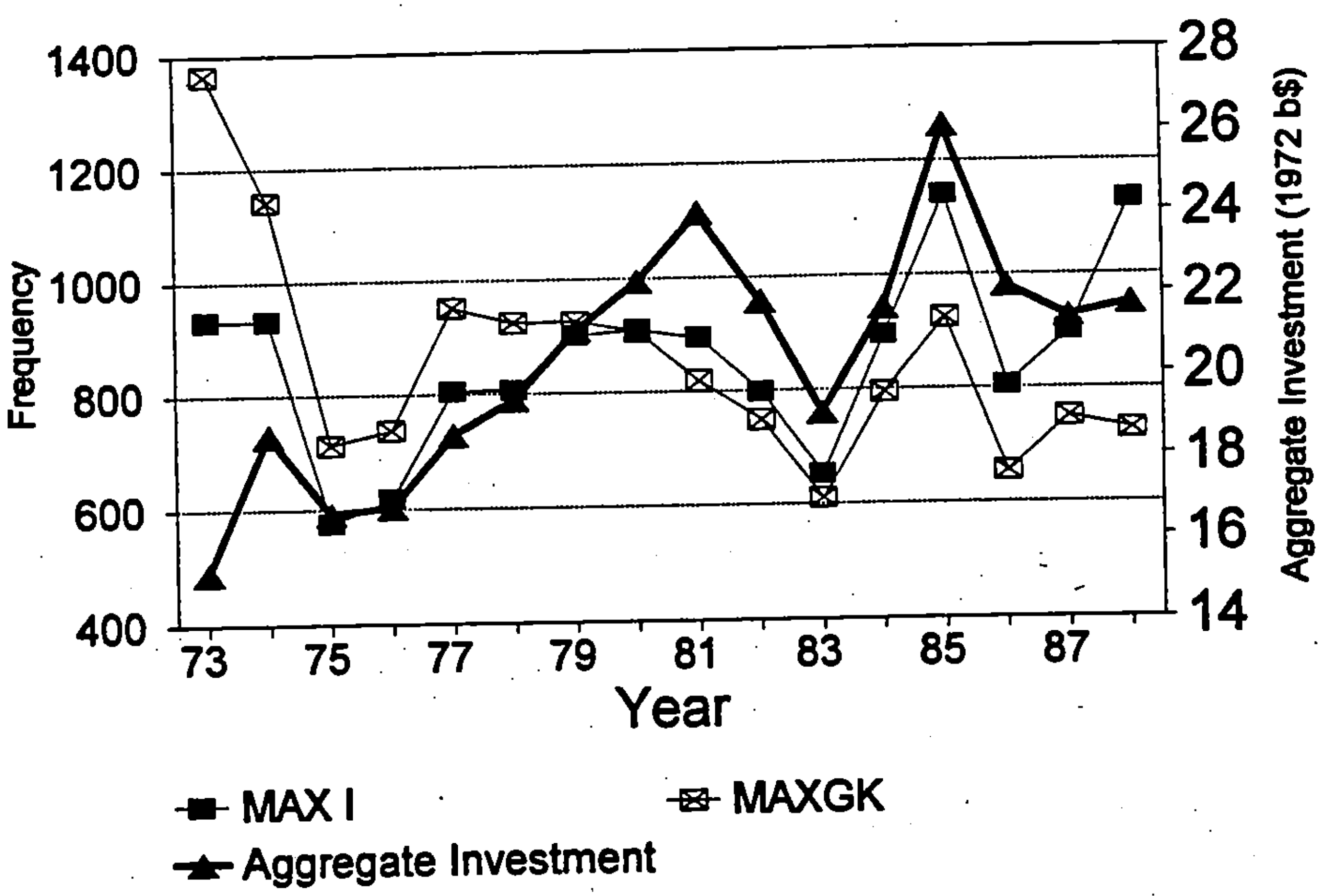


Figure 6: Aggregate Investment and Herfindahl of Investment

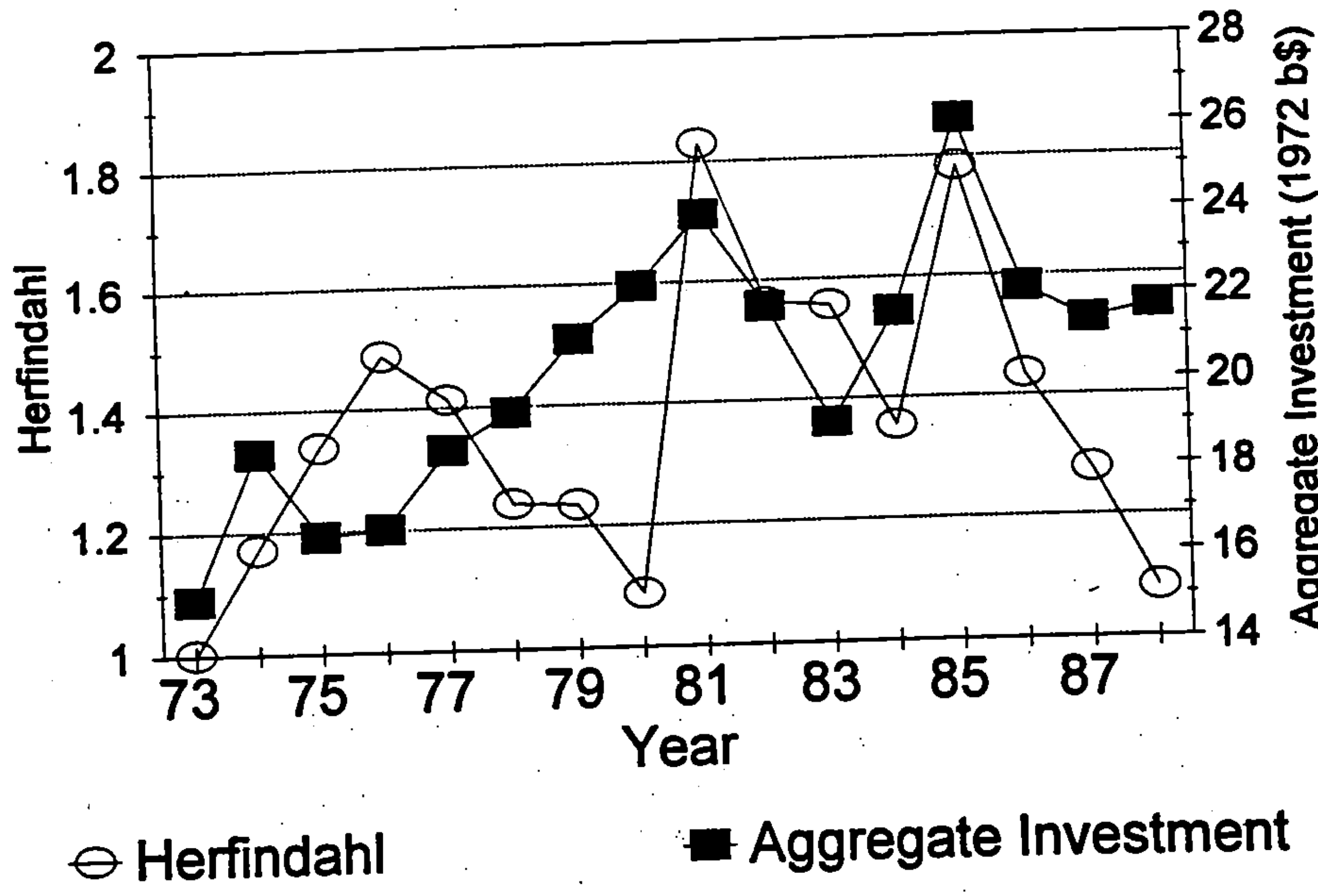
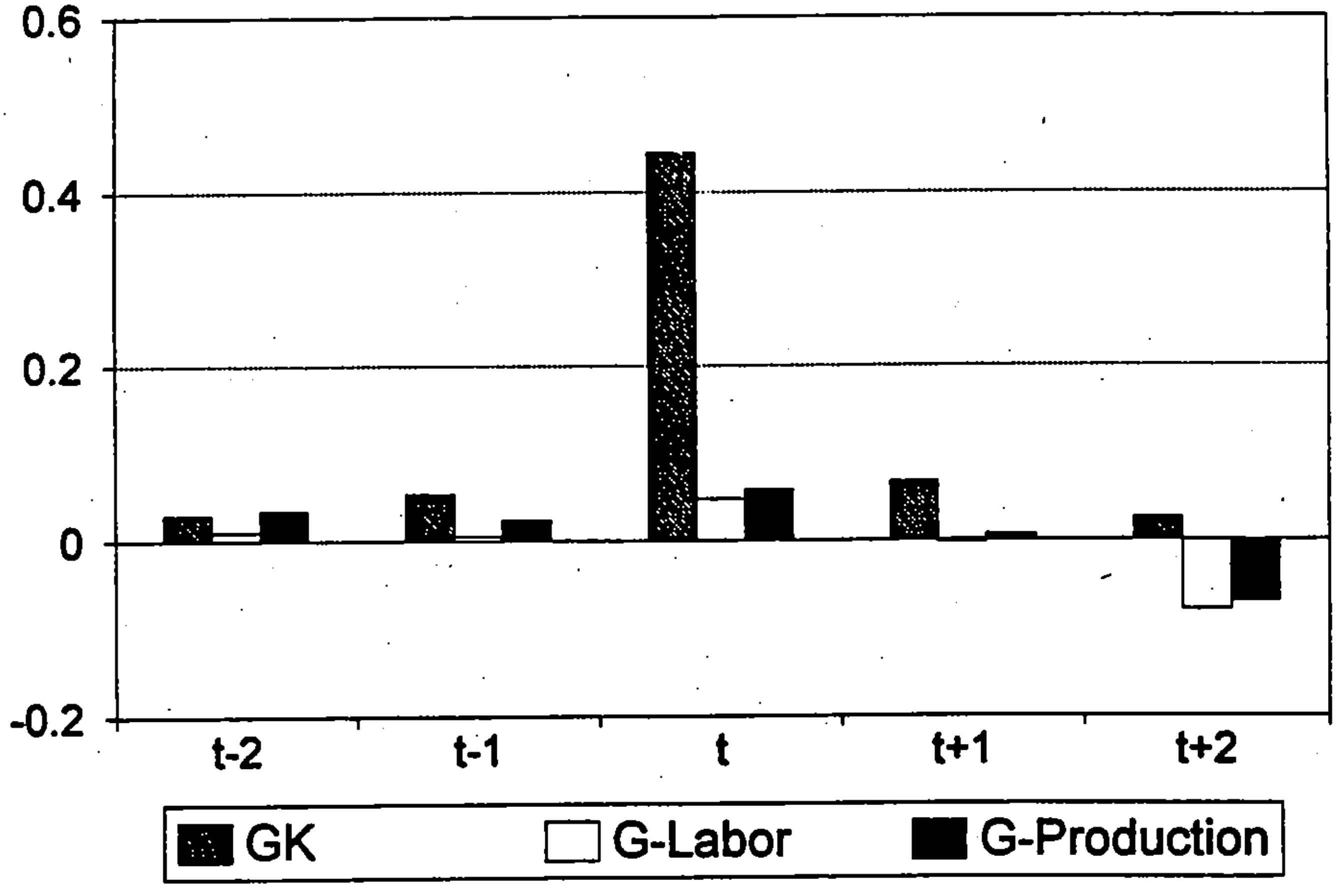
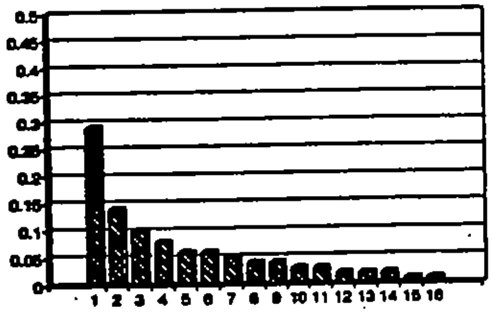


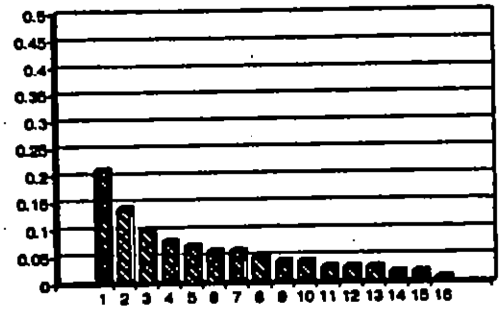
Figure 7: Mean Pre- and Post- Spike Performance, Full Sample



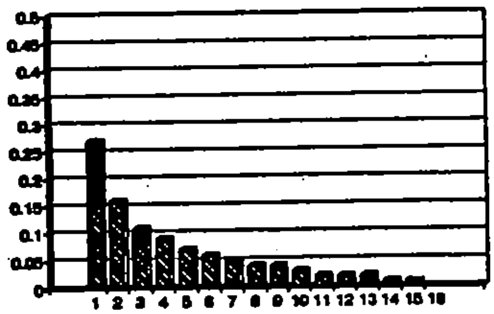
Investment Ranks
Meat Packing: SIC 2011



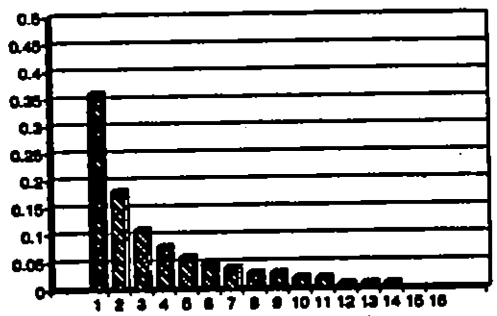
Investment Ranks
Bakery Products: SIC 2051



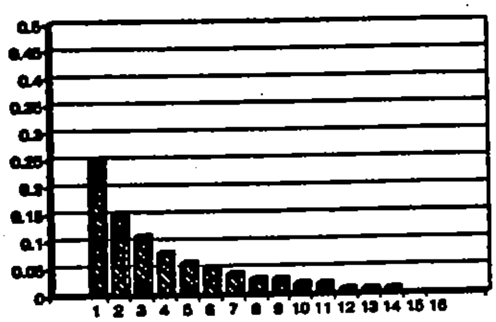
Investment Ranks
Cotton Weaving Mills: SIC 2211



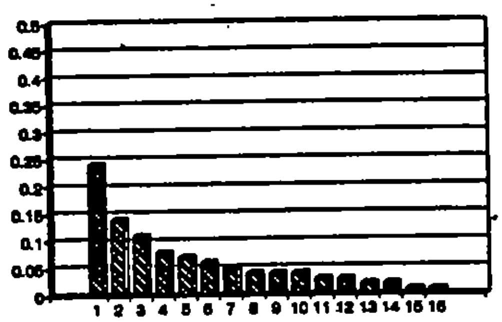
Investment Ranks
Womens and Misses Dresses: SIC 2335



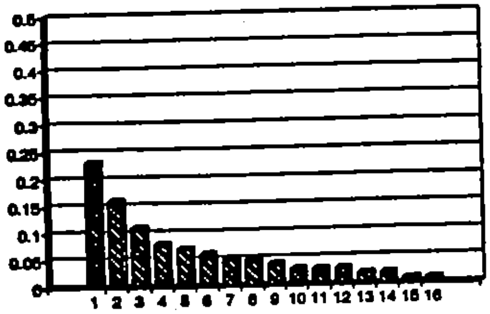
Investment Ranks
Wood Furniture: SIC 2511



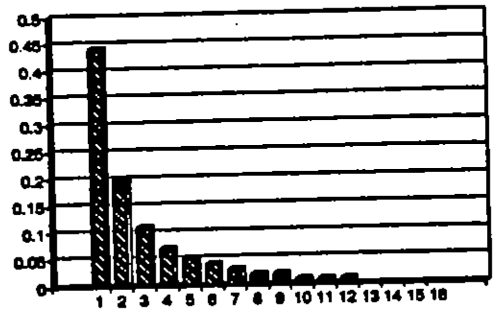
Investment Ranks
Paper Mills: SIC 2621



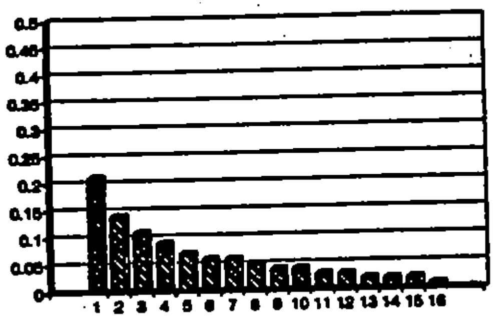
Investment Ranks
Letterpress Printing: SIC 2751



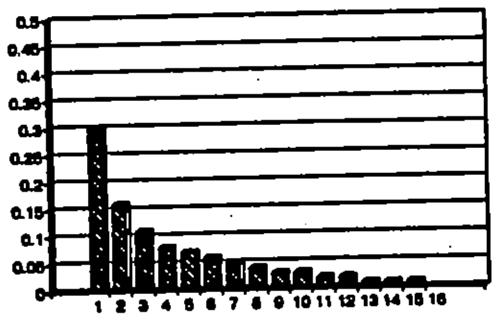
Investment Ranks
Industrial Gases: SIC 2813



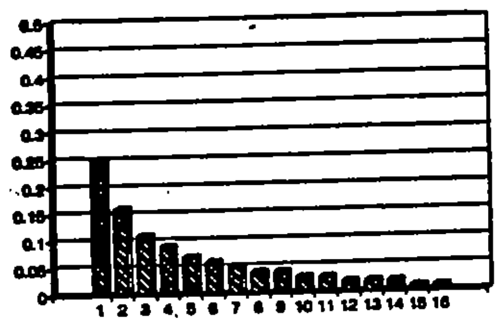
Investment Ranks
Pharmaceuticals: SIC 2834



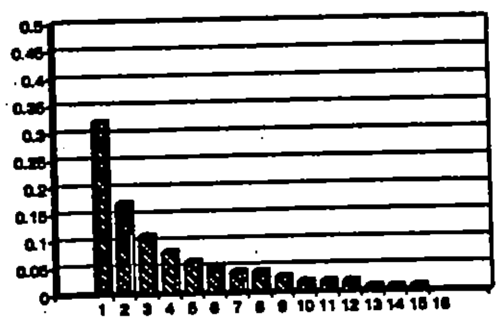
Investment Ranks
Fertilizers: SIC 2870



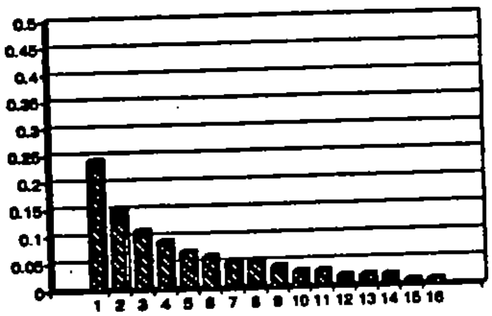
Investment Ranks
Petroleum Refining: SIC 2911



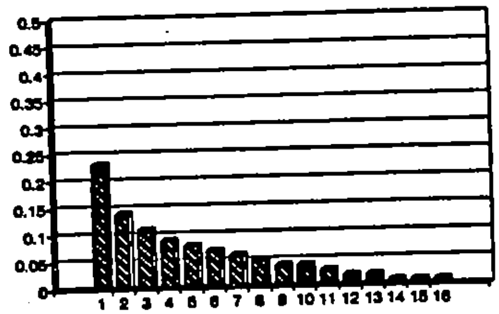
Investment Ranks
Hydraulic Cement: SIC 3241



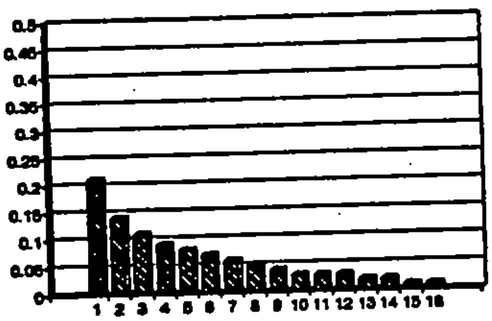
Investment Ranks
Steel Blast Furnaces: SIC 3312



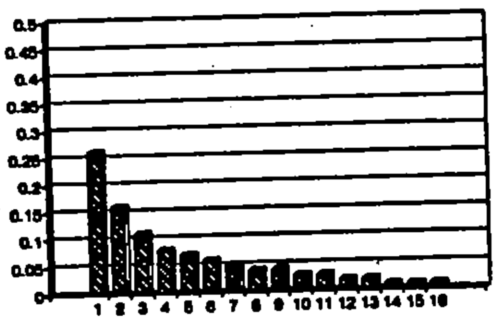
Investment Ranks
Computer Equipment: SIC 3573



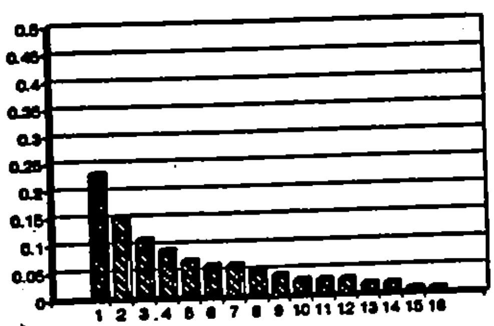
Investment Ranks
Semiconductors: SIC 3674



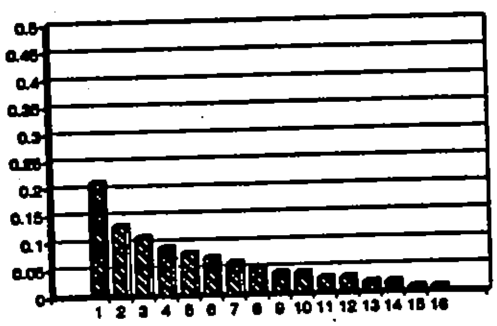
Investment Ranks
Automobile Assembly: SIC 3711



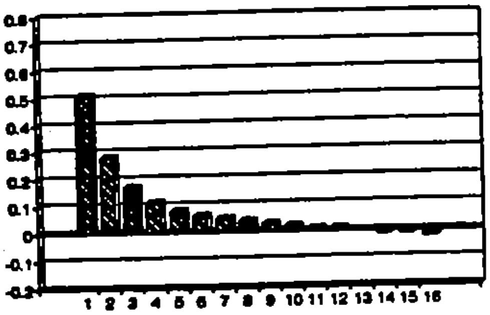
Investment Ranks
Scientific Instruments: SIC 3811



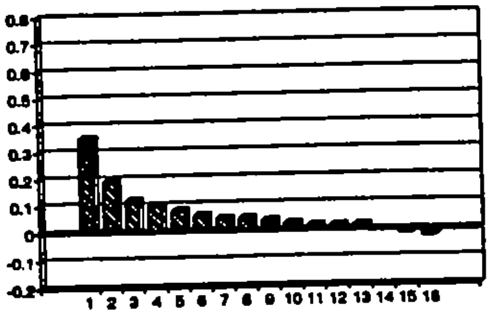
Investment Ranks
Medical Equipment: SIC 3841



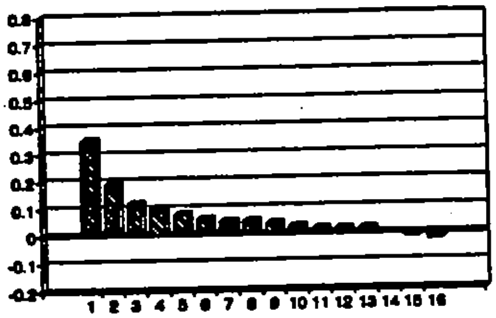
Capital Growth Ranks
Meat Packing: SIC 2011



Capital Growth Ranks
Bakery Products: SIC 2051

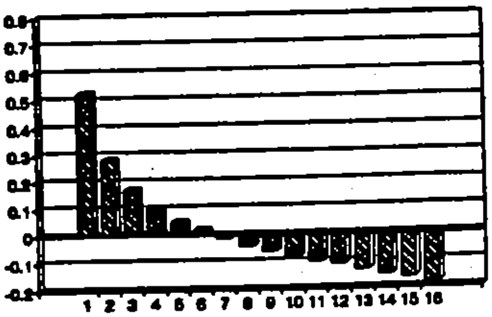


Capital Growth Ranks
Cotton Weaving Mills: SIC 2211



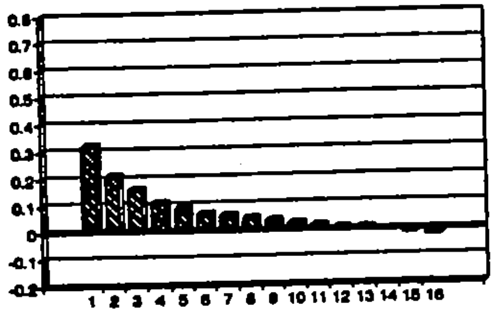
Capital Growth Ranks
Womens and Misses Dresses: SIC 2335

Capital Growth Ranks
Wood Furniture: SIC 2511

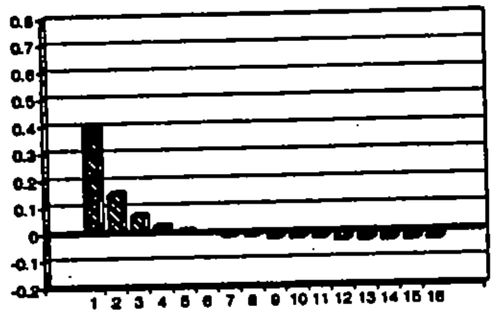


Capital Growth Ranks
Paper Mills: SIC 2621

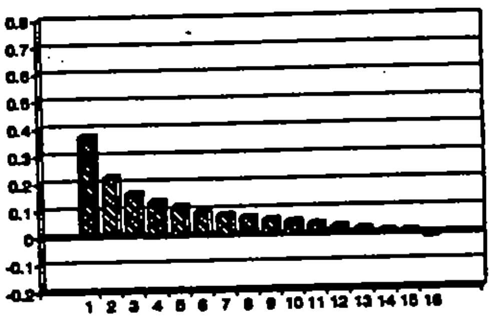
Capital Growth Ranks
Letterpress Printing: SIC 2751



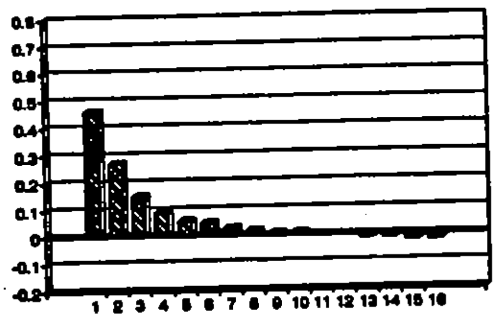
Capital Growth Ranks
Industrial Gases: SIC 2813



Capital Growth Ranks
Pharmaceuticals: SIC 2834

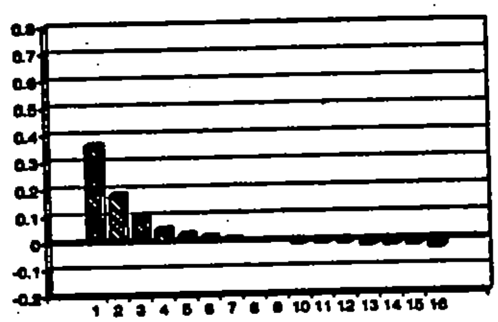


Capital Growth Ranks
Fertilizers: SIC 2870

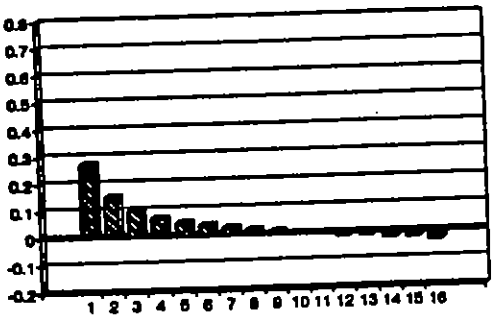


Capital Growth Ranks
Petroleum Refining: SIC 2911

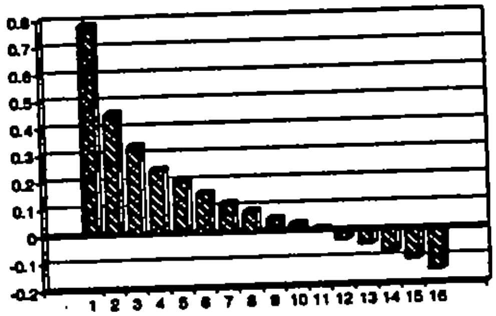
Capital Growth Ranks
Hydraulic Cement: SIC 3241



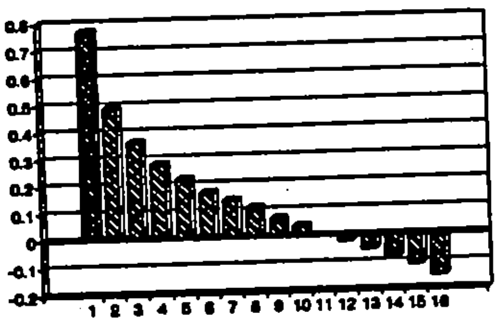
Capital Growth Ranks
Steel Blast Furnaces: SIC 3312



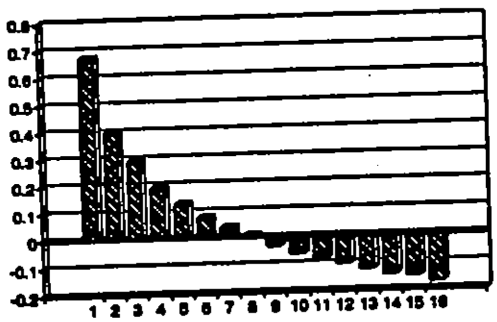
Capital Growth Ranks
Computer Equipment: SIC 3573



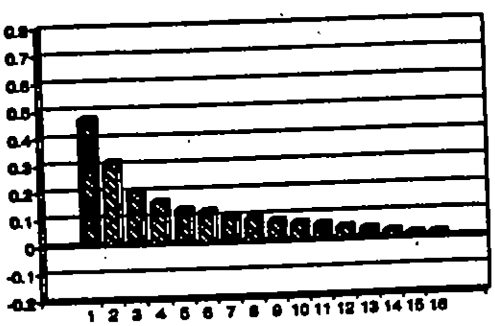
Capital Growth Ranks
Semiconductors: SIC 3674



Capital Growth Ranks
Automobile Assembly: SIC 3711



Capital Growth Ranks
Scientific Instruments: SIC 3811



Capital Growth Ranks
Medical Equipment: SIC 3841